

# Kennedy Space Center's Command and Control System

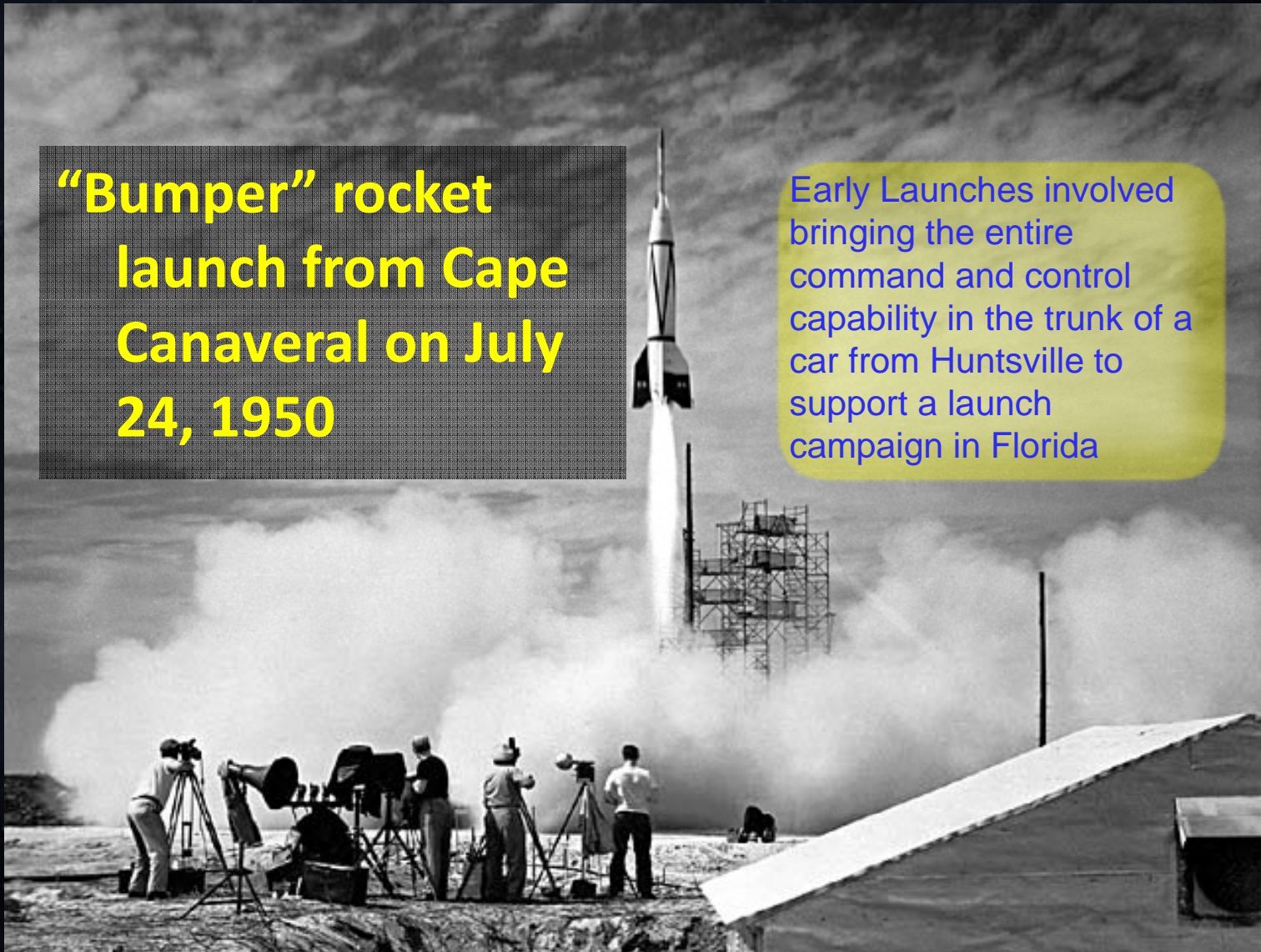
“Toasters to Rocket ships”

1950s

## The Beginning

**“Bumper” rocket  
launch from Cape  
Canaveral on July  
24, 1950**

Early Launches involved bringing the entire command and control capability in the trunk of a car from Huntsville to support a launch campaign in Florida





1960s

# Apollo

As human spaceflight  
drove the  
development of  
larger and more  
complex launch  
vehicles,

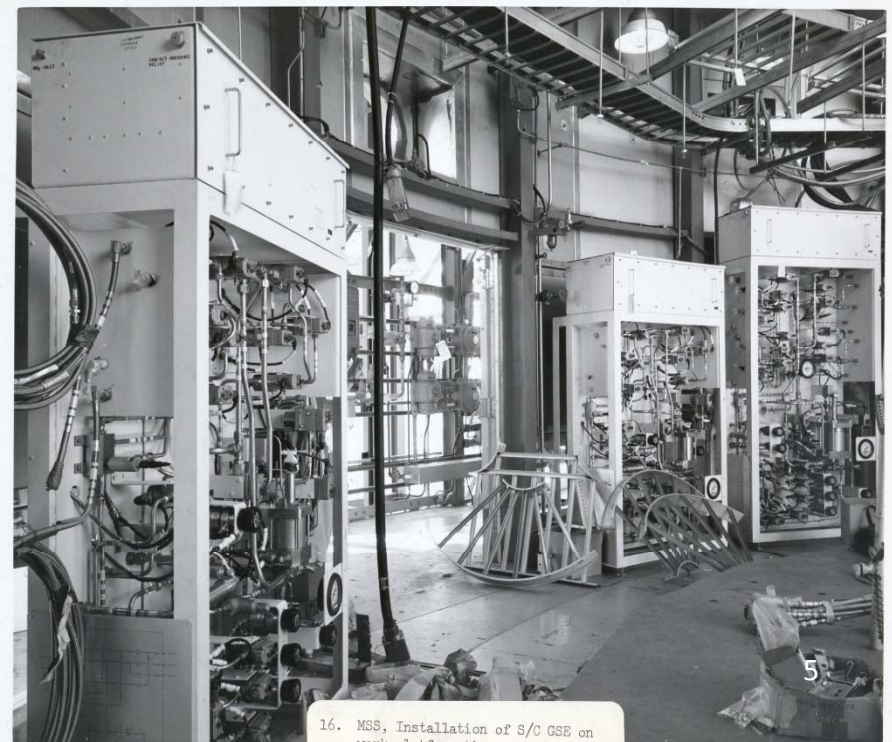




1960s

# Apollo

The number of actions that needed to be performed for launch increased, while the timing between those actions became more critical thus forcing the development of automated ground processes for the Saturn rocket



16. MSS, Installation of S/C GSE on work platform 4A



1960s

# Apollo



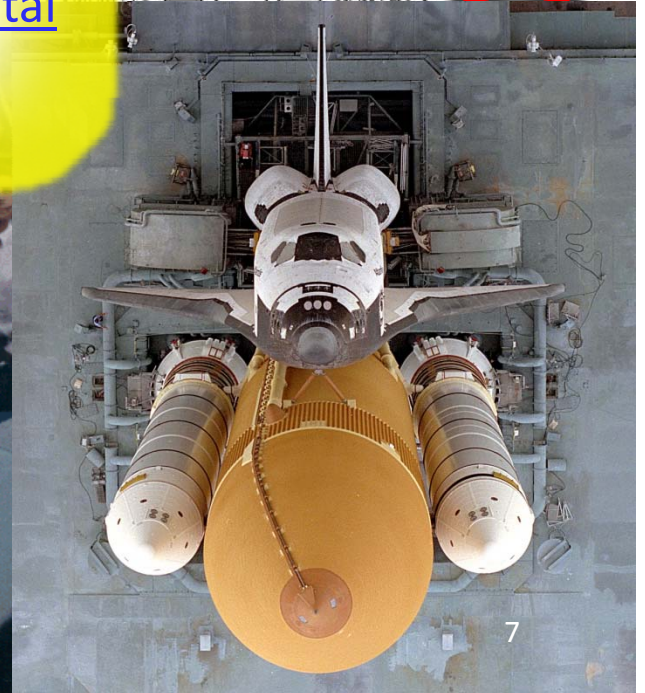
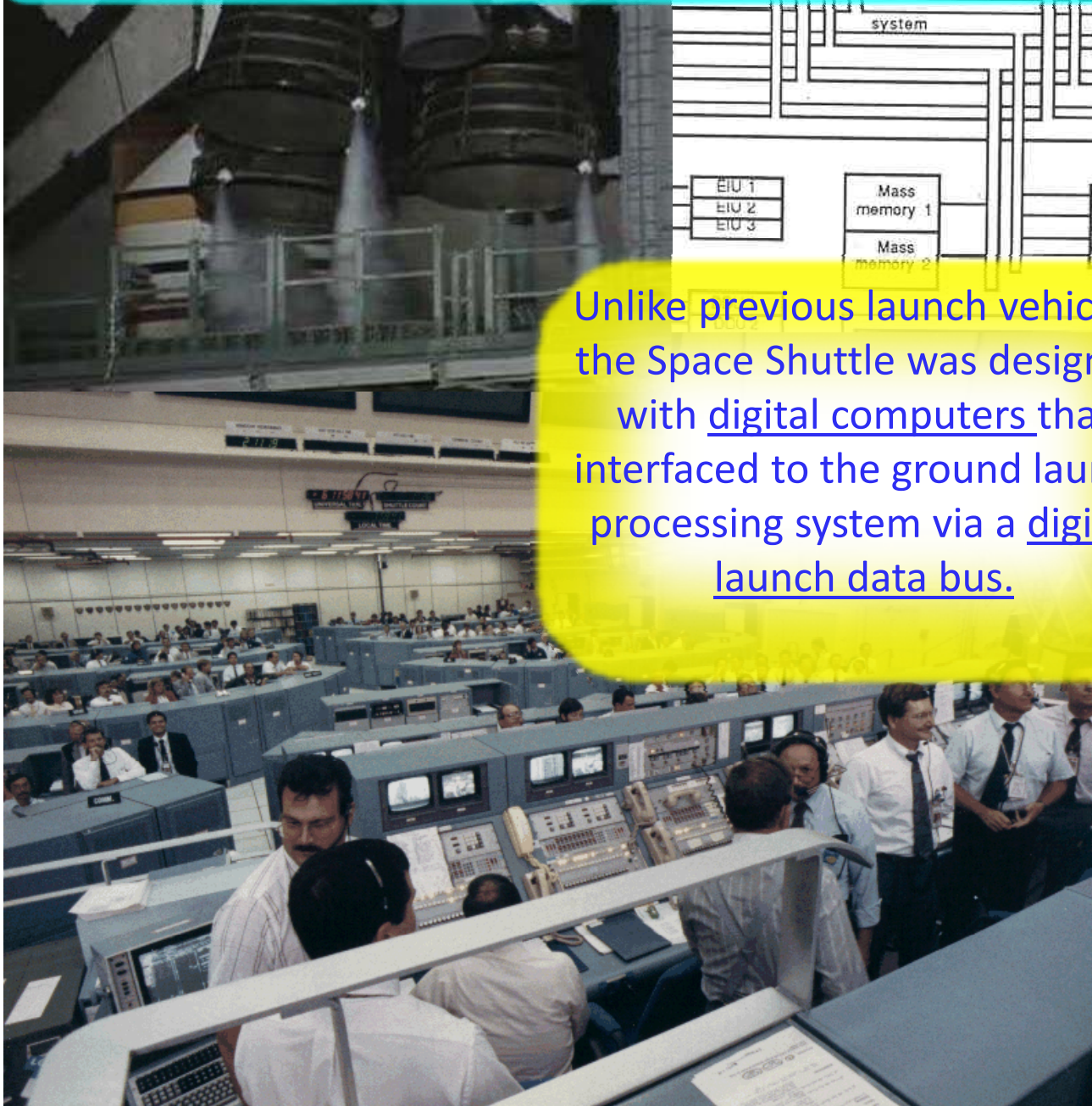
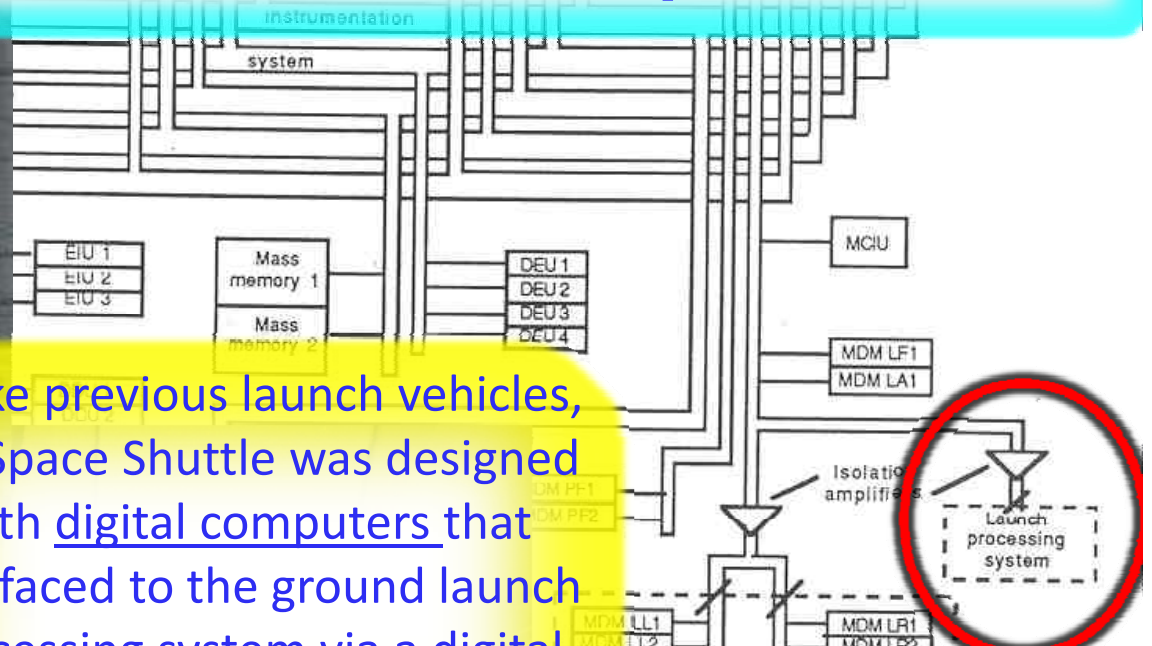
Human launch controllers managed the launch process with a hardware-only system of switches, gauges, lights and dials that required a dedicated human interface to perform every function, throw every switch, and verify every light and gauge until the Apollo vehicle lifted off from the pad



1970s

# Space Shuttle

Unlike previous launch vehicles, the Space Shuttle was designed with digital computers that interfaced to the ground launch processing system via a digital launch data bus.





1970s

# Space Shuttle

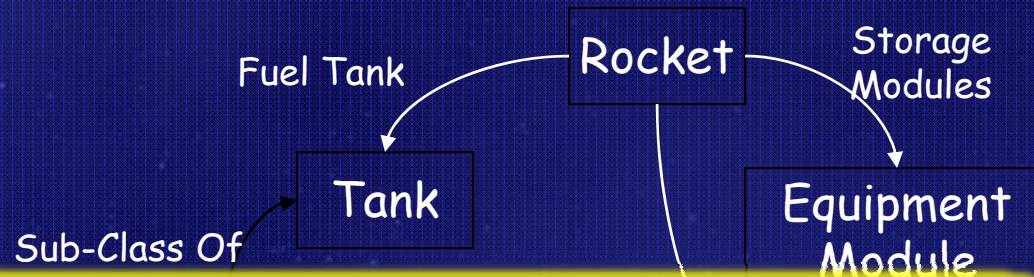
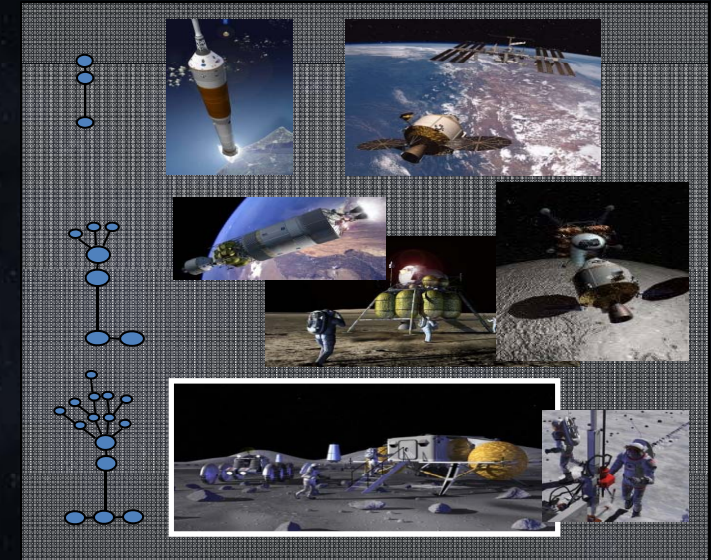
As part of the Shuttle Launch Processing system a custom software language that was developed in-house to allow operations engineers (operators) to directly specify command and response behavior without them needing specialized software development skills.

This provided the benefit that operators could troubleshoot both the vehicle and GSE as well as the software that ran in the Command and Control system.

~2006 - 2010

# Constellation/Exploration

With the advent of the Constellation Program NASA KSC determined that a new command and control System would be required for ground processing the fleet of exploration vehicles.

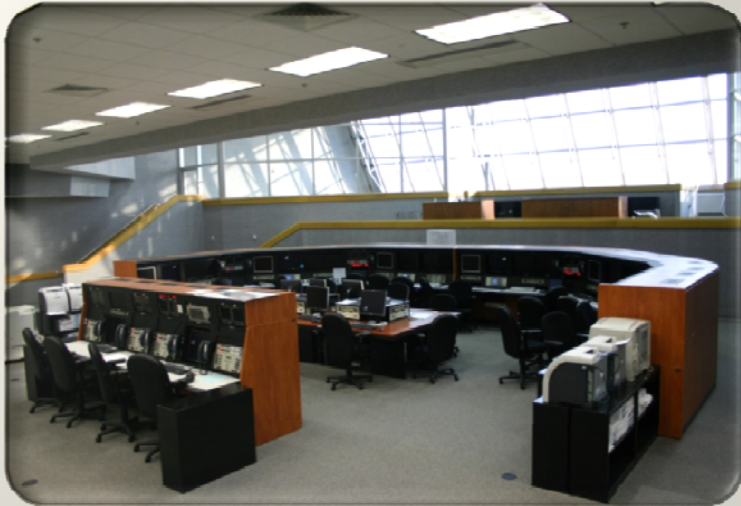


For the first time in thirty years, NASA would not be upgrading an existing command and control, it would be creating a new system from the ground up.



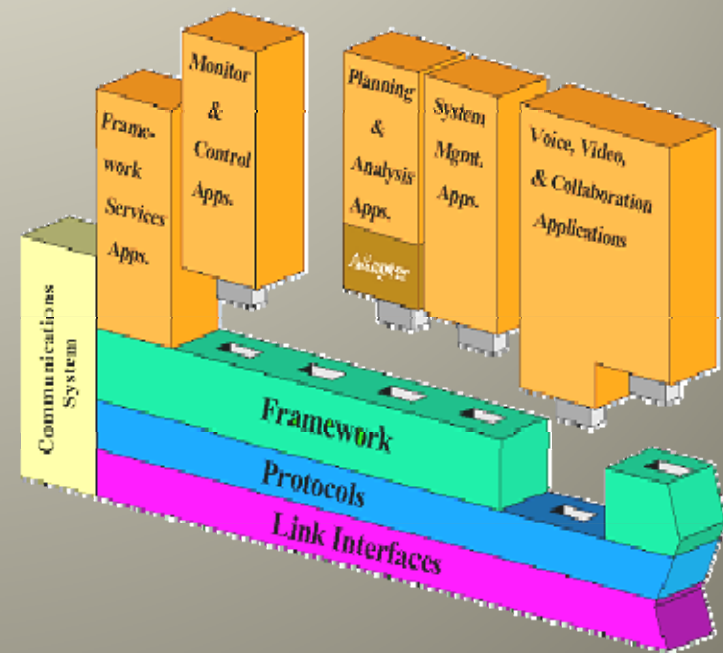
~2006 - 2010

## Constellation/Exploration



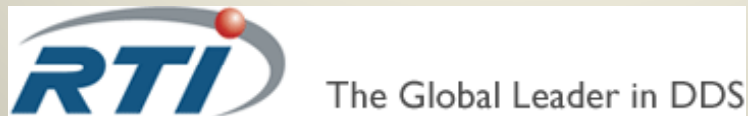
To support the concept of ground processing a variety of exploration vehicles the design approach of using a “Standards Based Architecture” for a command and control system was chosen.

A Standards Based Architecture maximizes the use of COTS software and developing a minimal amount of “Glue Code” for integrating the commercial products to support the emerging Ground Processing Support requirements.

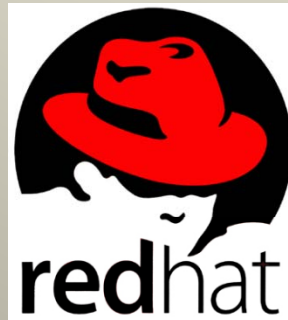




A robust market enabled the “Standards Based Architecture” and  
“maximized COTS” Approach



Rational. software



OS COMET®

Rockwell  
Automation



OpenSplice™ | DDS



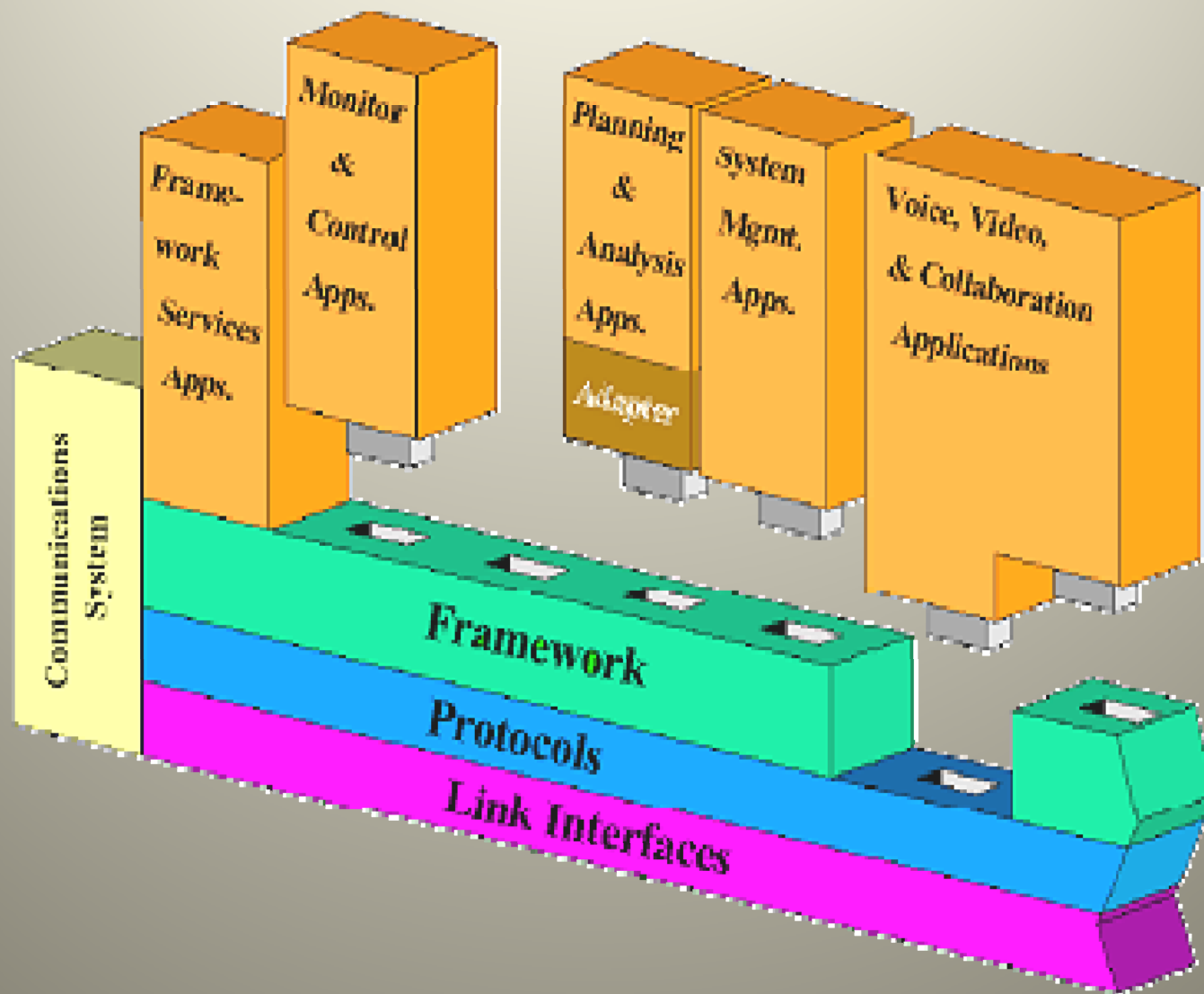
Klocwork

# Approach for using COTS in the Launch Control System

- Background
  - Decision made to deploy a Standards Based Architecture to support Kennedy Space Center Ground Operations Command and Control Requirements
- Risk
  - Essential ground processing command and requirements not defined in time for initiation of procurements
- Mitigation
  - Develop an architecture that deploys the COTS for best “requirement fit”
    - Allocation of command processing
      - Control room servers and displays for human-in-the-loop, situational awareness requirements
      - Front end, embedded systems, for real-time closed loop control
  - Allocate the emerging ground operation support requirement to the suitable portion of the architecture based on closed-loop performance requirements
- Outcome
  - The Launch Control System architecture and design can accommodate numerous interfaces with a variety of command and control performance requirements
  - *From “Toasters to Rocket Ships”*



# LCS- Integration of Commercial Products





~2006 - 2010

# Constellation/Exploration

The Launch Control System design effort was based on three major architectural tenets.

First....

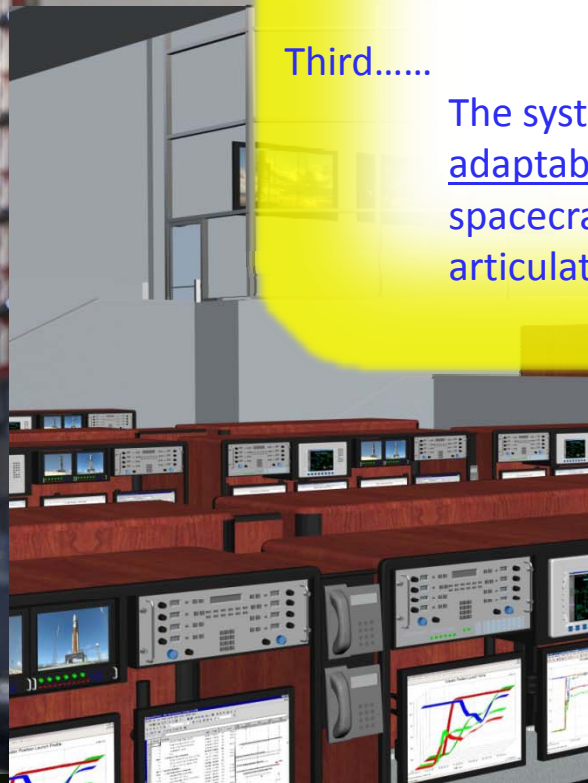
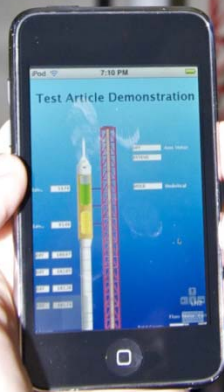
The system had to be sustainable for forty years.

Second....

The system had to be standards-based and not tied to a single vendor.

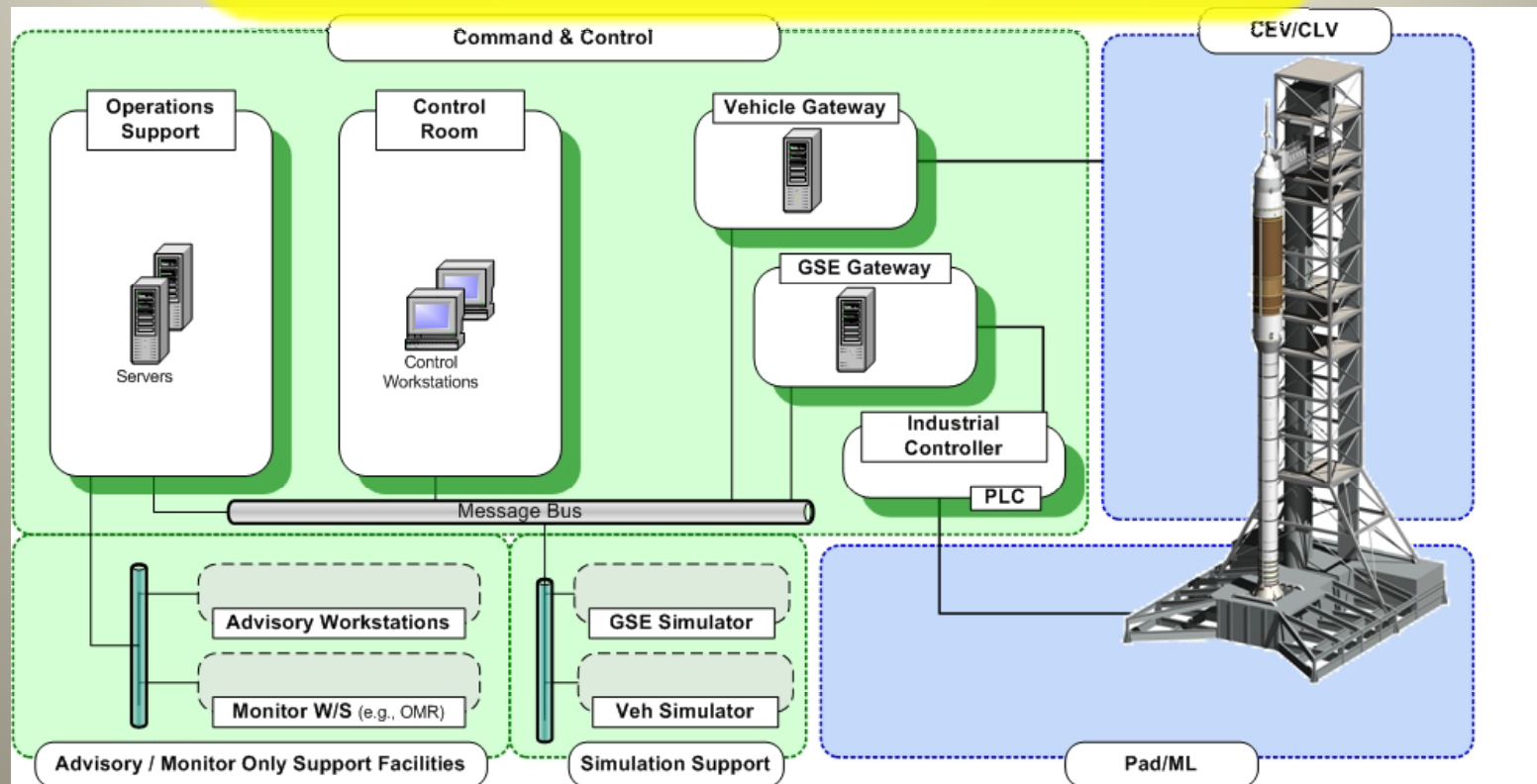
Third.....

The system had to be designed for flexibility and adaptability to support the requirements of future spacecraft and launch vehicles that could not be articulated in the present.



## Launch Control System

The LCS design is based upon the use of mature, industry accepted, hardware and software standards and products for command and control applications.



Specialized Software will be developed only when no suitable industry/government product is available.

# Vehicle & Ground Systems Interfaces

## General Characteristics

Design maximizes the use of industrial based process control products and COTS to configure a software communication and data distribution architecture rather than build one from scratch

## Launch Control System (LCS)

LCS – provides C&C functionality for vehicle processing.

## LCS Hardware Architecture

Control Room Workstation – Windows/Linux platforms providing Thin-Client Displays, Light-Weight Displays, and Application Display Clients

Application/Gateway/Display Servers – Unix/Linux platforms, Mid-Range, multi-processor servers providing Integrated Control Applications, Subsystem Control applications, reactive control, emergency vehicle safing, command processing and telemetry data publication.

Industrial Controllers – embedded control systems to provide closed loop control.

## LCS System Software Architecture

Isolation service layers providing common functionality, data logging services, networking services, recording services, commanding services, application framework, display framework and system monitoring and control.

## LCS Application Software

Processing Operations Applications for Orion/Ares I.  
Processing Operations Applications for LSAM/Ares V.

## LCS Simulation System

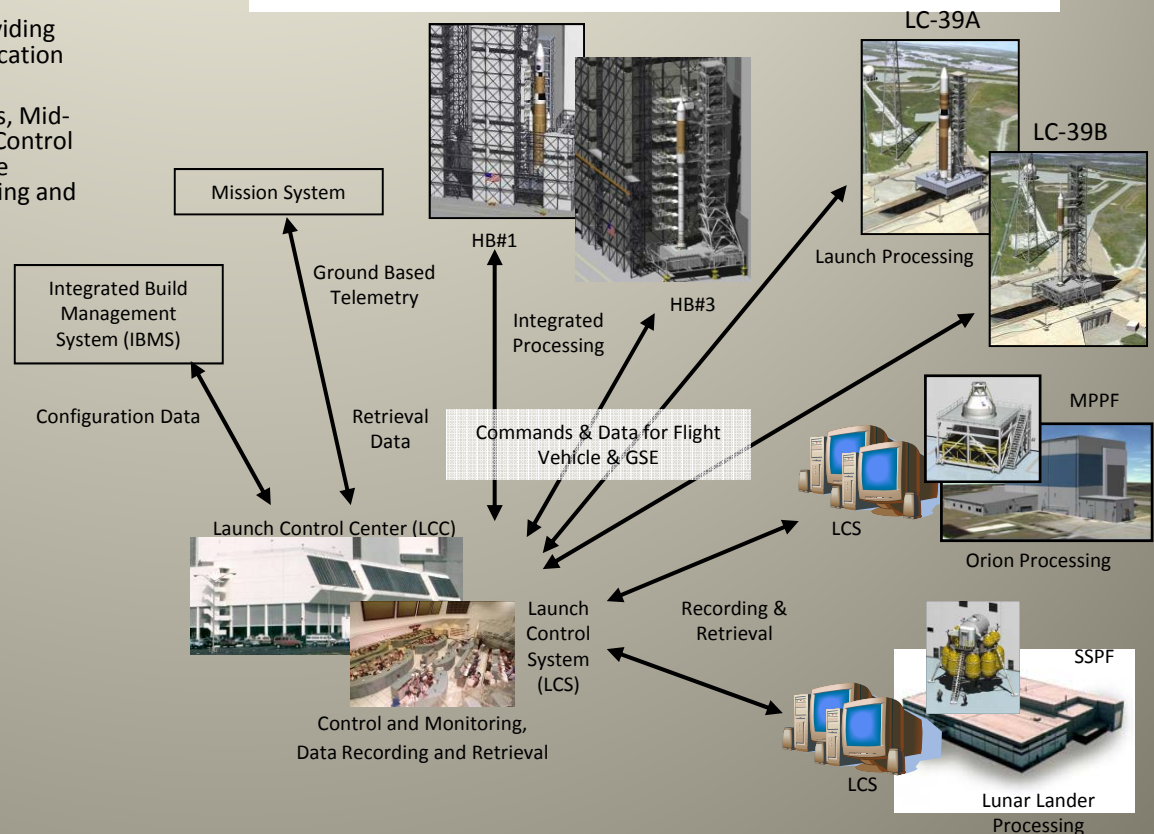
Missing element simulation, training, and testing support

## LCC Control Rooms

Firing Room 1 for Launch Vehicle Processing  
Firing Room 4 for Crew Exploration Vehicles

## Current Initiatives

Requirements allocation and system design.





# LCS Implementation To Date

Industry Standard Programmable  
Logic Control PLC technology installed to  
Interface to the Ground Support Equipment  
(Solenoids, Valves, Transducers)



# Industry standard Control Room supervisory Commercial-off –The shelf control systems installed



Modern User/Computer Interface  
Wireless technology  
Standard workstation interfaces  
EMI/EMC Hardened

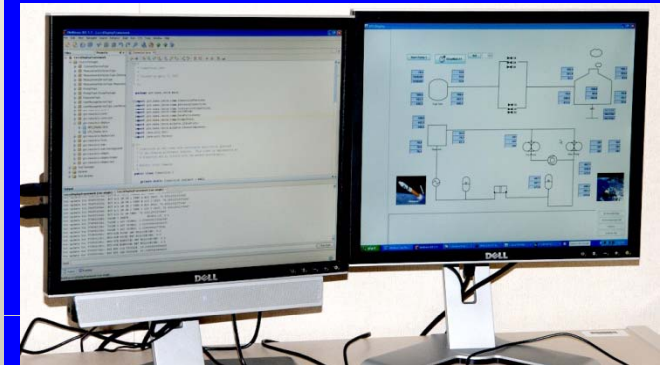
## Application Server



IBM P-570 Enterprise Class Server

- ◆ Data Distribution – RTI DDS
- ◆ Application Scripting Engine – Python
- ◆ Prototype Application – LH2 (Script and Tabular based)
- ◆ System Monitor and Control – IBM/Tivoli and HP Openview
- ◆ High Reliability Availability and Serviceability Technology – IBM Hypervisor and Robust N/W Switches

## User Workstation



Windows Based Dell Desktop

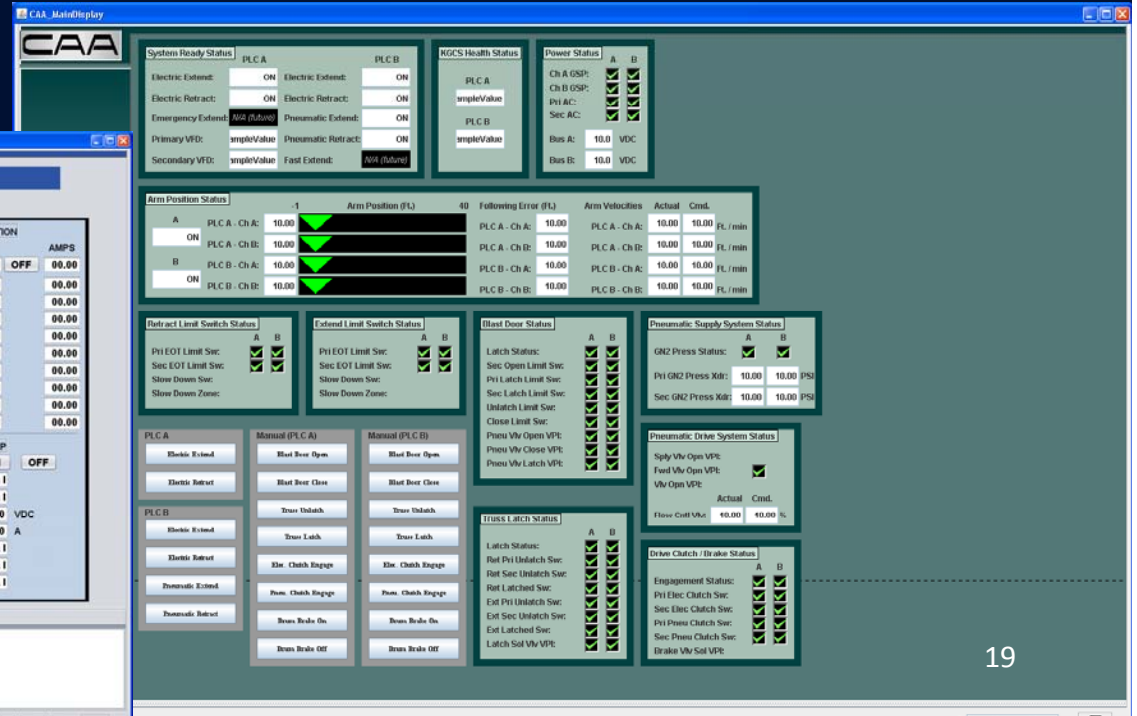
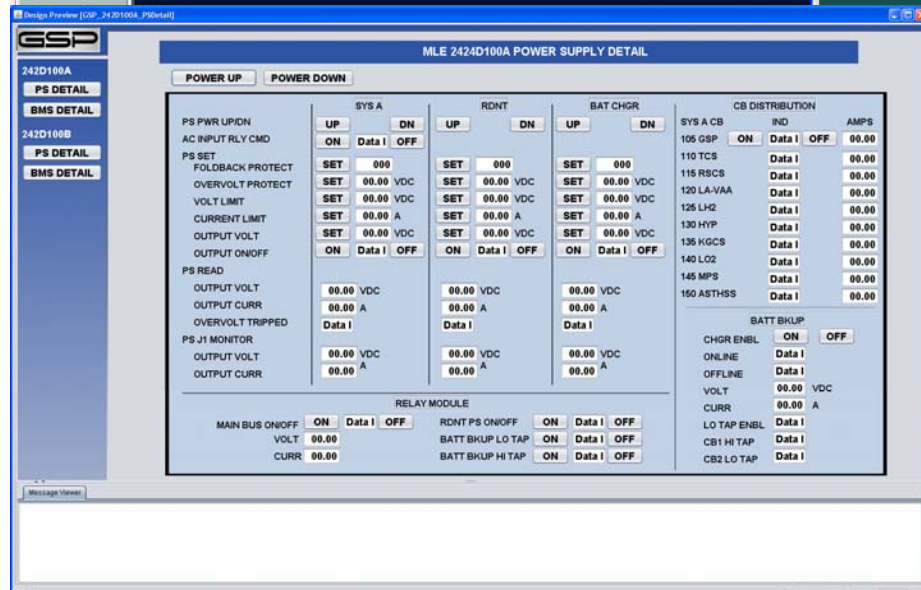
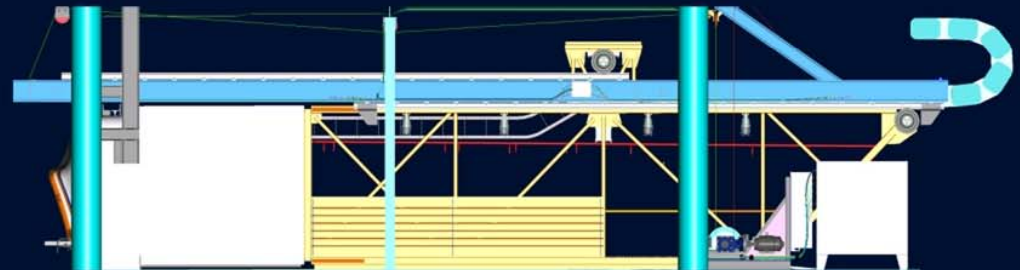
- ◆ Data Distribution – RTI DDS
- ◆ Display Engine – Java
- ◆ Prototype Displays – LH2 and PLC
- ◆ Health & Status Monitor – Tivoli and HP Openview

## Gateway Interface Server



- ◆ PLC/GSE Data Processing – Harris OS Comet
- ◆ Telemetry and Command Processing – Harris OS Comet
- ◆ Data Distribution – RTI DDS
- ◆ Health & Status Monitor – HP Openview

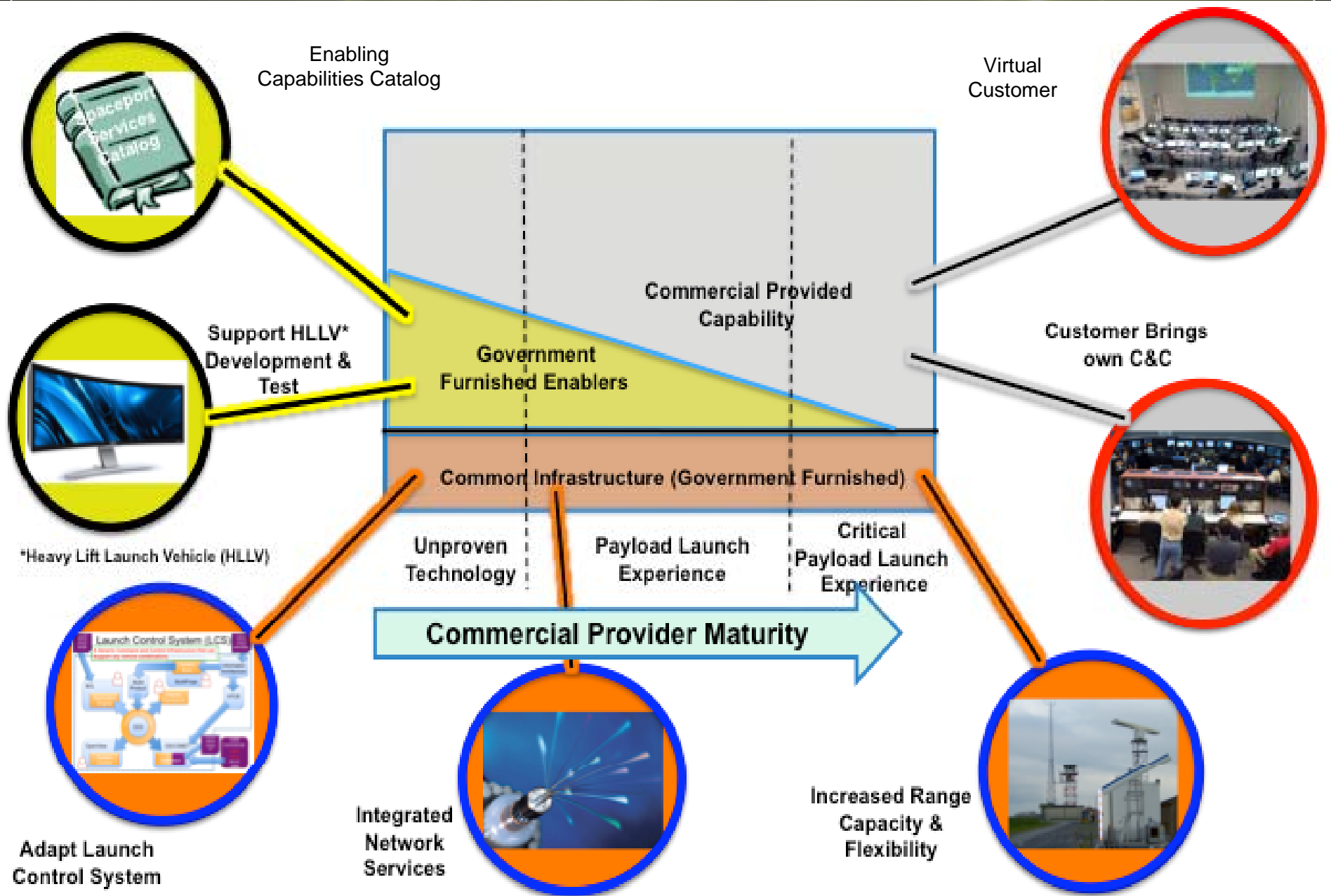
# Industry standard display tool technology in use for the command and control of flight and ground systems





2011 and beyond

Future

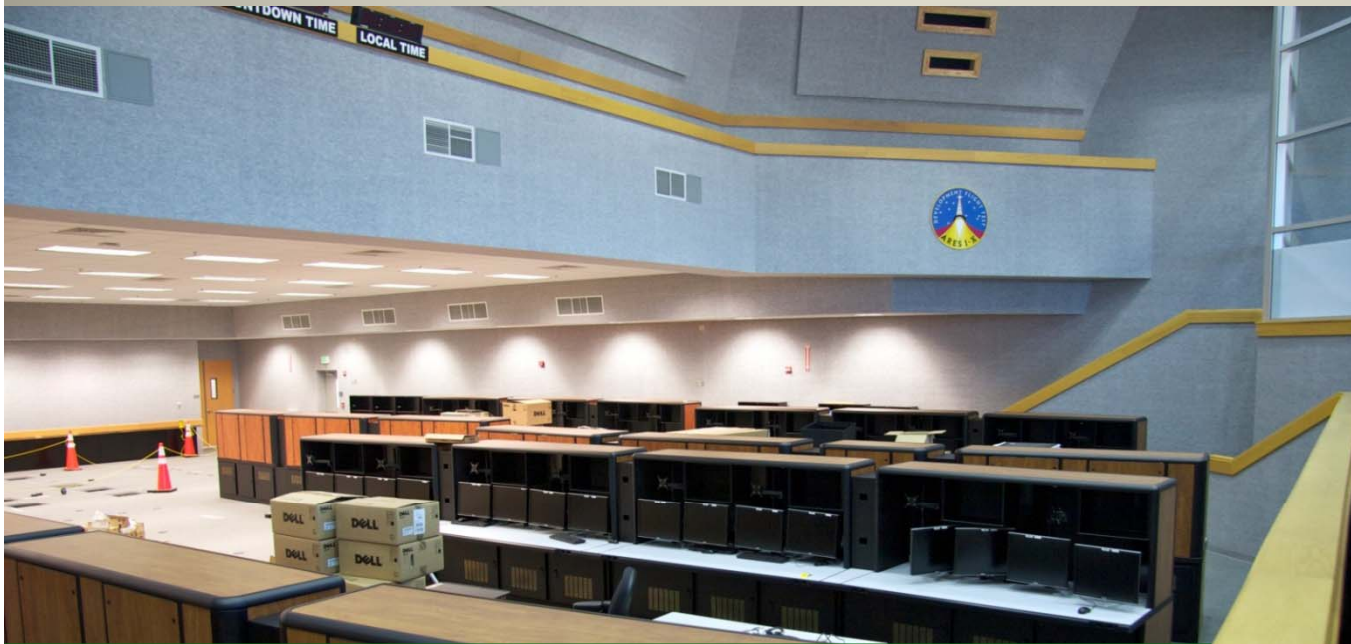


## Transitioning from Constellation to 21 Century Launch Complex, Heavy Lift Support, Commercial Crew, etc.

- Team is working to re-validate the system design in terms of building blocks of capabilities.
- Phased in FY11 and FY12 to provide a basic Command and Control capability.
- Generic System to support unique development for any customer starting at the end of FY12.

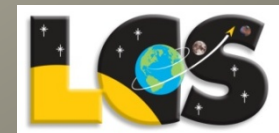
### Refine and Revise:

- *Architecture Interfaces*
- *COTS Products*
- *Ground Operations Reqs.*
- *Agility – Rapid Deployment Approach*
- *Hardware deployment*
- *Software capabilities*
- *Maintain CMMI Certification*
- *Provide Flexible Firing Room configuration for variety of customers*



Command & Control System is being developed to support three Roles:

- 1) Common Infrastructure for SLS development and test flights.
- 2) Provide assured access for mission assurance / NASA Insight.
- 3) Enabling capabilities to compliment commercial provider resources.

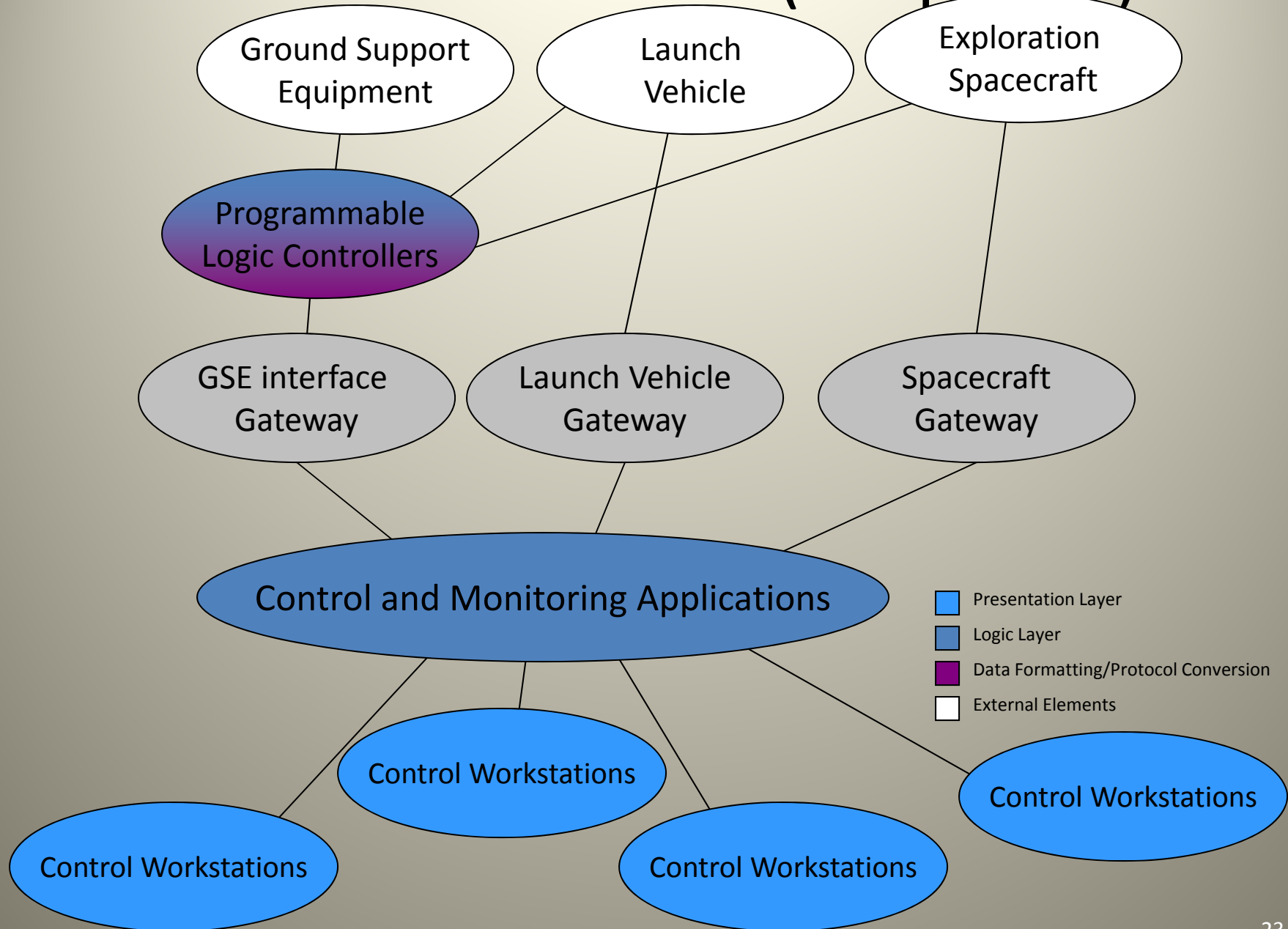


# Designing an architecture that can Accommodate Ambiguity

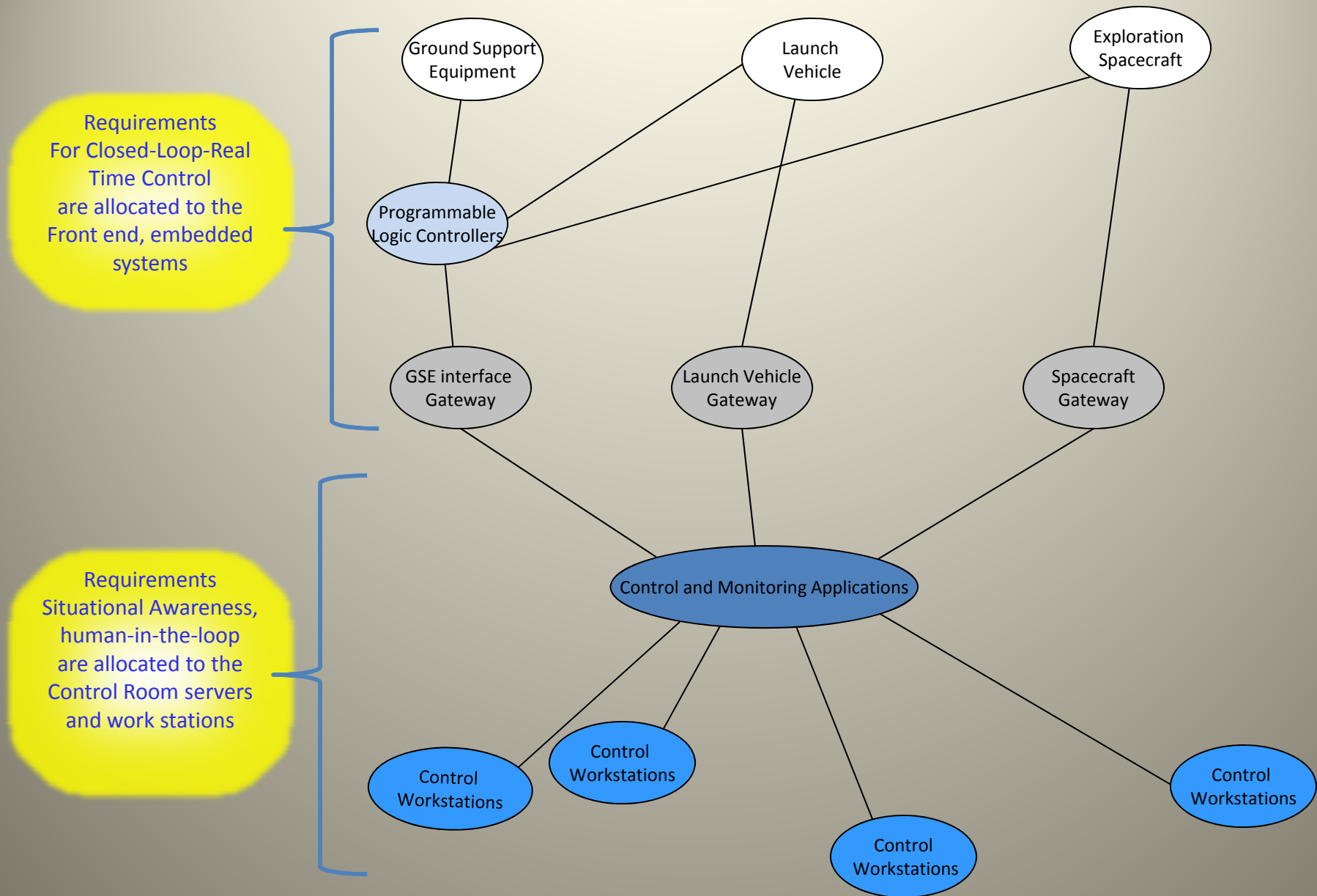




# LCS Architecture (Simplified)

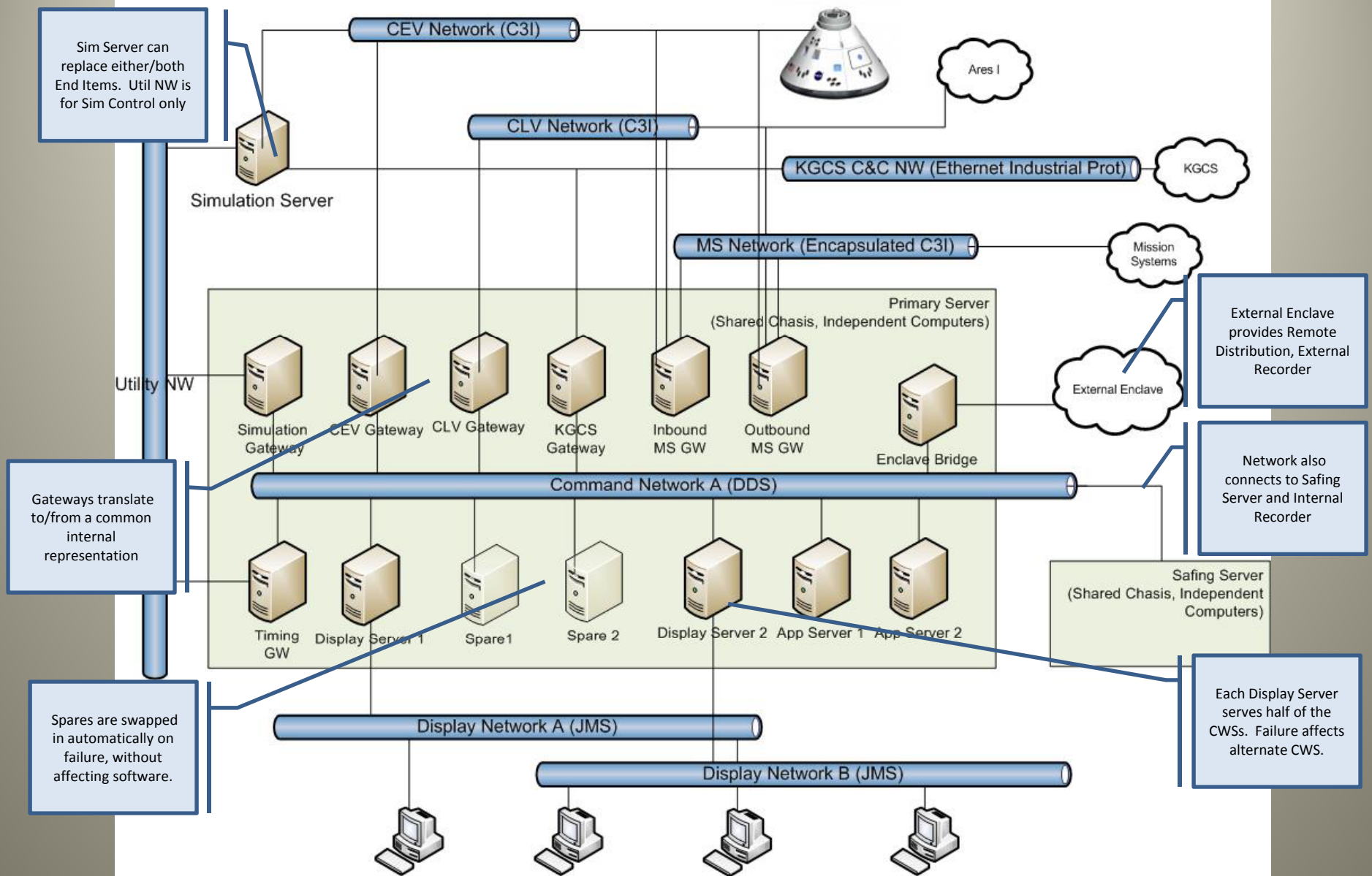


# Allocation of Control Illustration





# LCS / Firing Room Architecture (Simplified)



# LCS Software Architecture

## Simulation

- GSE/Veh Shuttle Simulation

## Industrial Controllers

- PLC application
- GSE math model

## Information Architecture

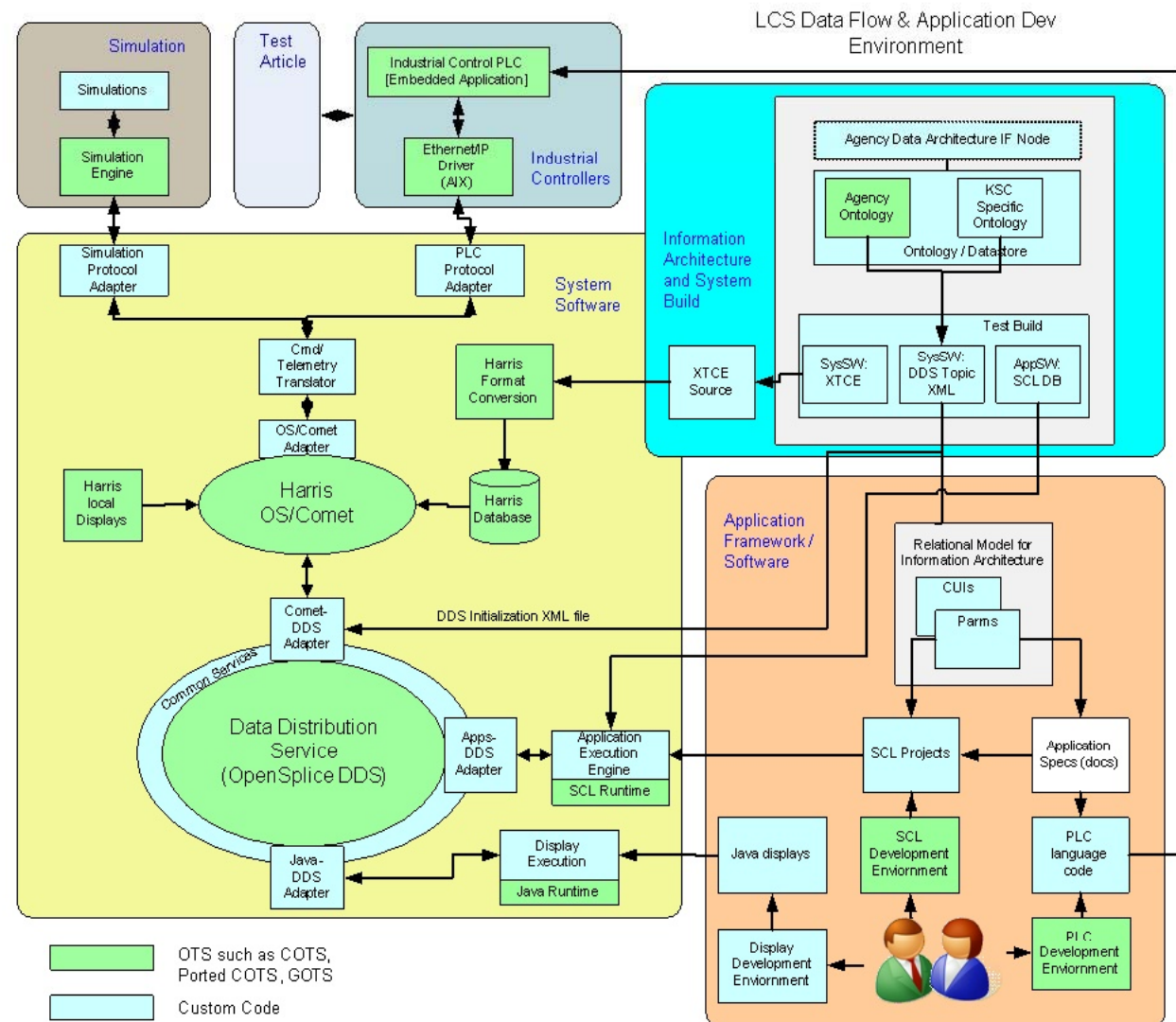
- Data Ontology
- Build Products

## System Software

- Data Distribution
- Isolation layers
- Telemetry processing

## Application Framework/Software

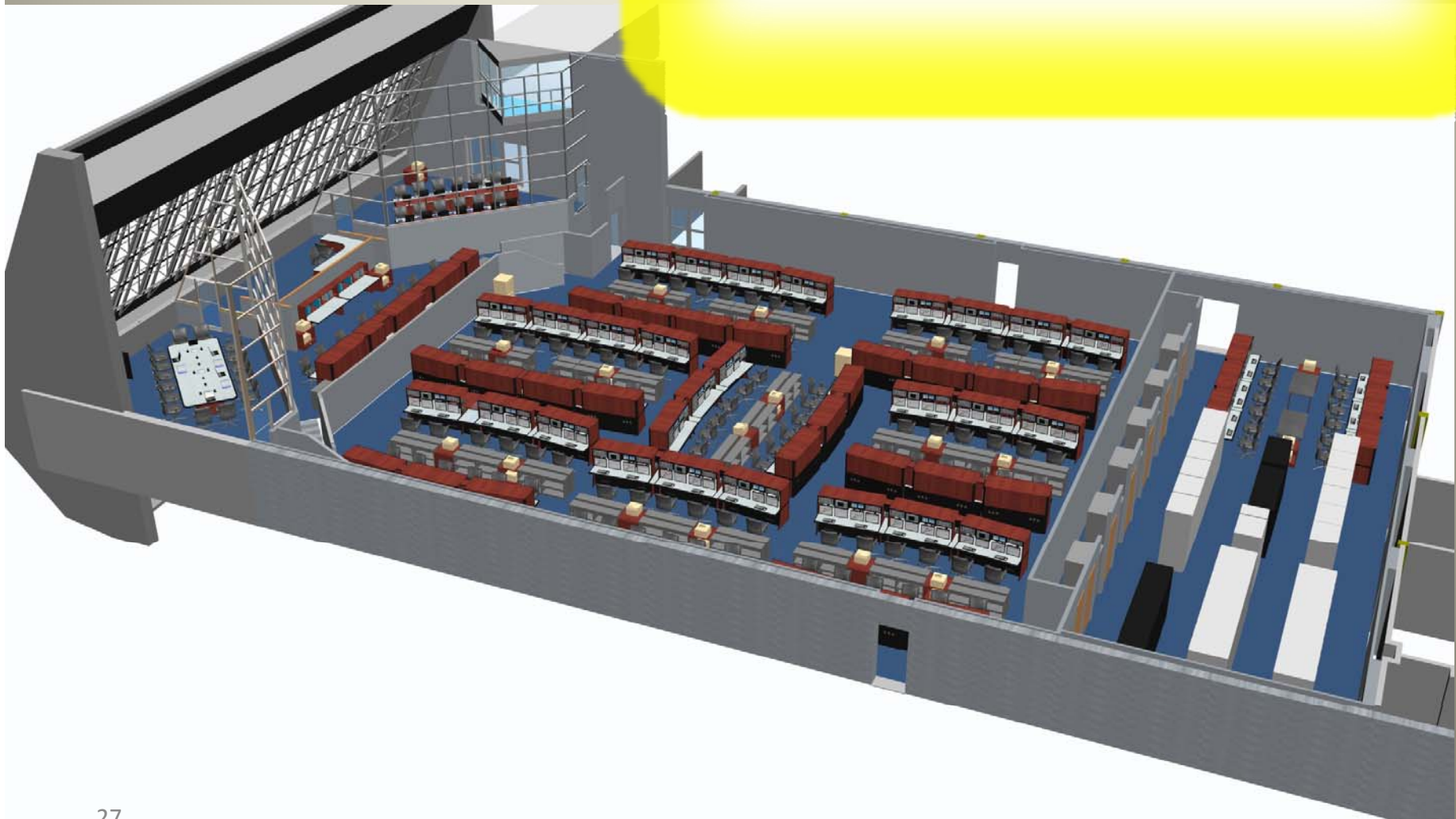
- User displays
- Control applications





*Kennedy Space Center  
Exploration Control Room*

*Under Construction*





*Kennedy Space Center  
Exploration Control Room*

*The new control room is being  
designed  
To support multiple customers with  
different requirement*



# *Kennedy Space Center Exploration Control Room*

*Phase one of the new control room was  
completed September 2010*







## *Kennedy Space Center Exploration Control Room*

*Phase two of the new control room, which includes the main floor layout is scheduled to be completed Spring 2011*



# Welcome to the Florida Spaceport

Today is Tuesday April 14, 2020

Commercial Crew launch from Pad 39-B to ISS at 8:47 AM **ON TIME**

Mars Communications Satellite launch from Pad 41 at 1:13 PM **ON TIME**

Commercial satellite launch from Pad 37 at 6:35 PM **ON TIME**

**Tomorrow April 15, 2020**

Space Hotel passenger launch from Pad 39-A at 11:00 AM **ON TIME**

*Notice: Use of Virtual Reality sensory implants while traveling on Florida's Spaceport is illegal*